Scientific Visualization Research Issues

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One of the primary challenges to visualization research today is in creating and deploying visualization tools with proven utility. Such tools need to be effective at giving humans the ability to understand multi-valued, multi-dimensional, time-varying, multi-modal data in the context of scientific applications. In general, I am most interested in problems where the visualization tools are exploratory, i.e., are being used to look at data where we don't know quite what we're looking for. This is in contrast to expository tools, which are used to clearly display something that is understood. I will below describe a few promising approaches to overcoming this challenge in the context of exploratory scientific visualization applications.

First, research to characterize the strengths and weaknesses of display environments and visualization methods will help to ensure that users can interact with data as efficiently and effectively as possible. Display environments today run the gamut from small-screen, low-resolution hand-held devices to high-resolution, large-screen displays as well as fully immersive, head-tracked, stereo, tiled, surround-screen projection systems (Caves) and head-mounted displays (HMDs), some even with tactile and haptic feedback. Intermediate forms include semi-immersive, head-tracked stereo workbenches and fishtank displays, and the ubiquitous desktop workstation. Currently, the advantages of the different environments have only begun to be studied. One issue with the richer environments is that many interactive visualization tools that use them are built upon desktop metaphors and don't take sufficient advantage of their unique capabilities. Characterizing the environments and visualization methods that use them, both quantitatively and qualitatively, will help to identify these capabilities so that they can be leveraged.

Second, research in fluid interaction techniques is needed. By fluid interaction, I mean user interface actions that minimize cognitive attention requirements, allow faster interaction without sacrificing robustness, involve actions that can be integrated into motor memory, provide a streamlined workflow where commands are unified with data parameters to minimize motor and visual disruptions, and minimize user interface modes so that distractions are less disruptive. Expertise in multimodal, post-WIMP and gestural interaction is critical for facilitating fuller use of the bandwidth of human interaction, improving robustness by making use of complementary interaction modalities, and more effectively leveraging human perceptual and motor skills. These techniques are likely to need to employ novel interaction metaphors, use proprioceptive cues and body motion in interaction, leverage the use of large displays in creative new ways, and create new visual metaphors for the underlying data.

Third, research into how to use visual design expertise to accelerate the development of effective visualization methods and interaction tools for displaying and interacting with large datasets will lead to more effective tools. Visual designers will need to be first class citizens in the development process. This implies a learning process both for the visual designers and for the visual computing toolsmiths that they work with. It also implies the development of tools that support the more efficient contribution of visual designers. We believe that incorporating this expertise has the potential to advance the field much more rapidly than it would otherwise do because the pitfalls discovered through centuries of visual design experience have been learned by visual designers and so can be avoided.

The potential impact of following these approaches to create more effective exploratory visualization tools is the more rapid advance of science and medicine across many disciplines.